Web Security III: CSRF Mitigation, SQL Injection

CS 1660: Introduction to Computer Systems Security

CSRF attacks

Browser performs unwanted action while user is authenticated

CSRF: via GET

```
bad-site.com:
   <a href="http://bank.com/transfer.php&acct=1234?amt=1000.00?...
```

- Bad practice: state change info encoded in GET request
- Can easily "replay" request

CSRF: via POST

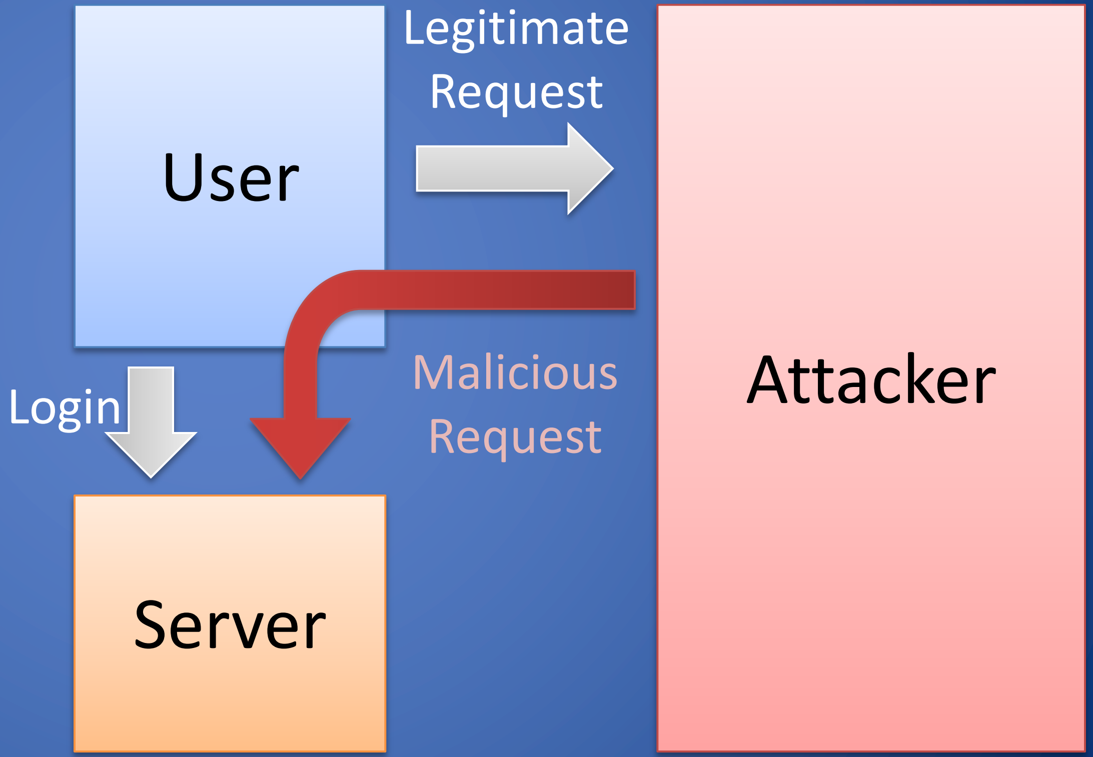
```
bad-site.com:

    <form action="https://bank.com/wiretransfer" method="POST"
          id=”bank">
    <input type="hidden" name="recipient" value="Attacker">
    <input type="hidden" name="account" value="2567">
    <input type="hidden" name="amount" value="$1000.00">
    …
    </form>
    document.getElementById(”bank").submit();
```

Is user is logged in, this will work!

CSRF Trust Relationships

- Server trusts user (login)
- User trusts victim enough to visit attacker's site/click link
- Attacker could be a hacked legitimate site



CSRF: How to defend?

How can we make sure a request comes from the intended origin?

One way: CSRF token

Server sends unguessable value to client, include as hidden variable in POST

```
<form action="/transfer.do" method="post">
<input type="hidden" name="csrf_token" value=”aXg3423fjp. . .">
[...]
</form>
```

On POST, server compares against expected value, rejects if wrong or missing

What does this prove?

CSRF Token: Mechanics

Different web frameworks handle tokens differently

- Set token per-session or per-request?
- Can include token directly in generated HTML, or use JS to set via cookie

How to generate the tokens?

- "Synchronizer token": server picks random value, saves for checking
- "Encrypted token": server sends encrypt/MAC of some value that can be checked without saving extra state (eg. user ID)

CSRF Token Types

Synchronizer Token

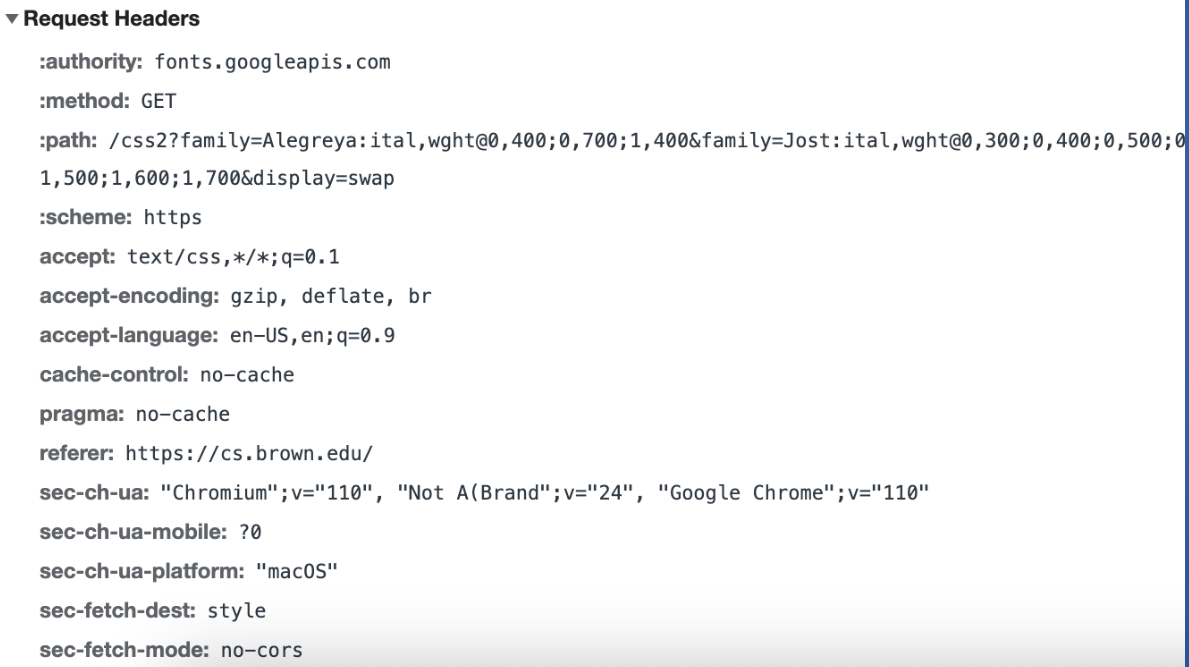
- Stateful
- Value randomly generated with large entropy
- Mapped to user's current session
- Server validates that token exists and is associated to user's session ID

Encrypted Token

- Stateless
- Token generated from user ID and timestamp
- Encrypted with server’s secret key
- Server validates token by verifying it and checking that it corresponds to current user and acceptable timestamp
- *Ex. Encrypted Token = HMAC-SHA-1(‘secret key’ + user ID + timestamp)*

Another way: checking headers

"Referer" [sic] header: URL from which request is sent



```
▼ Request Headers
    :authority: fonts.googleapis.com
    :method: GET
    :path: /css2?family=Alegreya:ital,wght@0,400;0,700;1,400&family=Jost:ital,wght@0,300;0,400;0,500;0
    1,500;1,600;1,700&display=swap
    :scheme: https
    accept: text/css,*/*;q=0.1
    accept-encoding: gzip, deflate, br
    accept-language: en-US,en;q=0.9
    cache-control: no-cache
    pragma: no-cache
    referer: https://cs.brown.edu/
    sec-ch-ua: "Chromium";v="110", "Not A(Brand";v="24", "Google Chrome";v="110"
    sec-ch-ua-mobile: ?0
    sec-ch-ua-platform: "macOS"
    sec-fetch-dest: style
    sec-fetch-mode: no-cors
```

Another way: checking headers

- Could check Referer header (or a different header) on request, see if it matches expected origin
- Browser limits how Referer header can be changed

=> Useful if you trust browser; but ultimately can be controlled by client

Strict SameSite Cookie Attribute

Controls how a cookie is sent when making a cross-site request

```
Set-Cookie: sessionid=12345; Domain=b.com; SameSite=Strict
```

- `SameSite=None`: Always send cookie for any request to b.com
- `SameSite=Strict`: Only send cookie if request from same site (ie, already on bob.com)
- `SameSite=Lax`: Only send if user is *navigating* to b.com (clicking a link), but not for in-page resource loads
  - As of 2020, default in most browsers not specified

Potential issues

- SameSite attribute set to Strict:
  - the browser will not include the cookie in any requests that originate from another site.
- A logged-in user follows a third-party link to a site:
  - they will appear not to be logged in, and will need to log in again before interacting with the site in the normal way
- Potential problems for usability and user tracking (e.g. Ads)
- Not all browsers have adopted default policy for websites that do not set SameSite
  - https://www.chromium.org/updates/same-site/

User Interaction

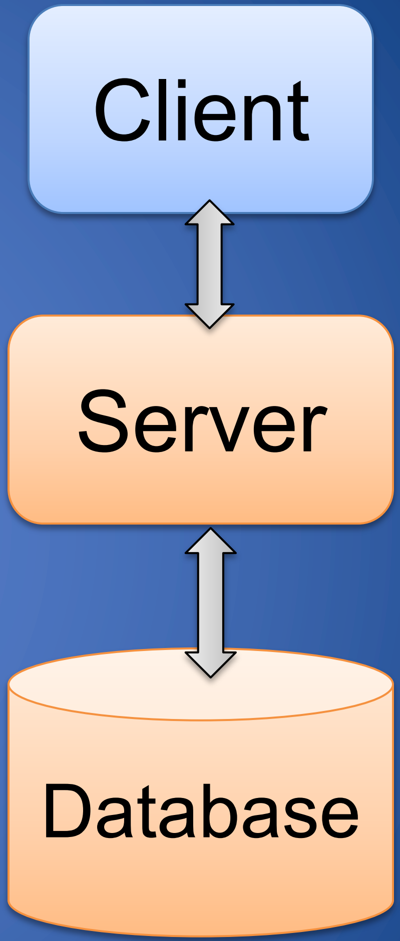
- Make a user reauthenticate, submit a one-time token, or do a CAPTCHA before performing any user-specific or privileged action on a website
- Scenario
  - Alice is logged into bob.com
  - Eve tricks Alice into visiting her page eve.com in another tab, which automatically redirects to send a malicious request to bob.com
  - Alice sees a login page for bob.com, but she thought she was visiting eve.com
- Potential issue: negatively impacts user experience

Example CSRF defenses: TryHackMe

Webapps + Databases

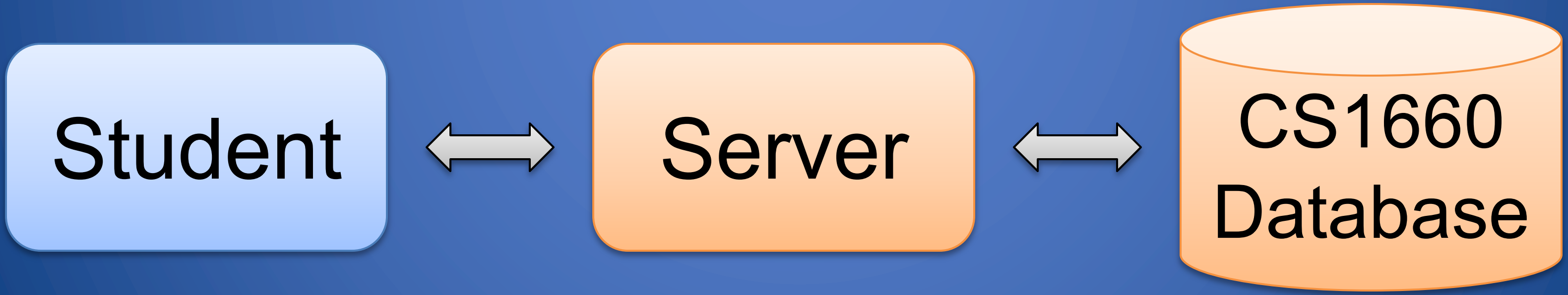
Most complex sites use a database

- Client-supplied data stored into database
- Access to database mediated by server
- Examples: Relational, Document oriented, …



The Great CS1660(TM) Database

- Student data stored into database
- Access to database mediated by server



Standard Query Language (SQL)

- Relational database
  - Data organized into tables
  - Rows represent records and columns are associated with attributes
- SQL describes operations (queries) on a relational database

attribute

record

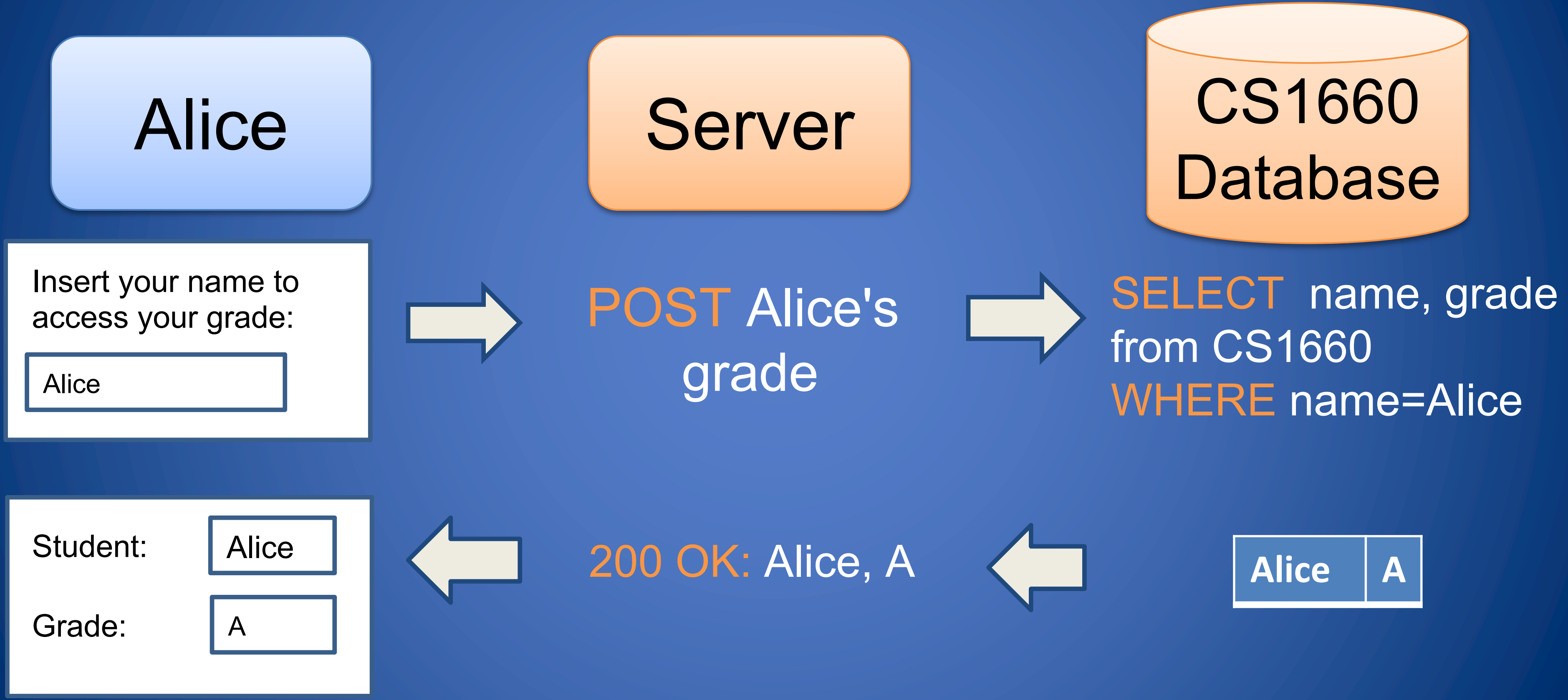
Name	ID	Grade	Password	admin
Bernardo	345	-	H(password)	1
Bob	122	C	H(bob123)	0
Alice	543	A	H(a3dsr87)	0
…	…	…	…	…

One query type: SELECT

```
SELECT attributes FROM table
    WHERE condition; -- comments
```

- Find records in table (FROM clause) that satisfy a certain condition (WHERE clause)
- Result returned as table (attributes given by SELECT)

SELECT: Data flow



Insert your name to access your grade:

Alice

POST Alice's grade

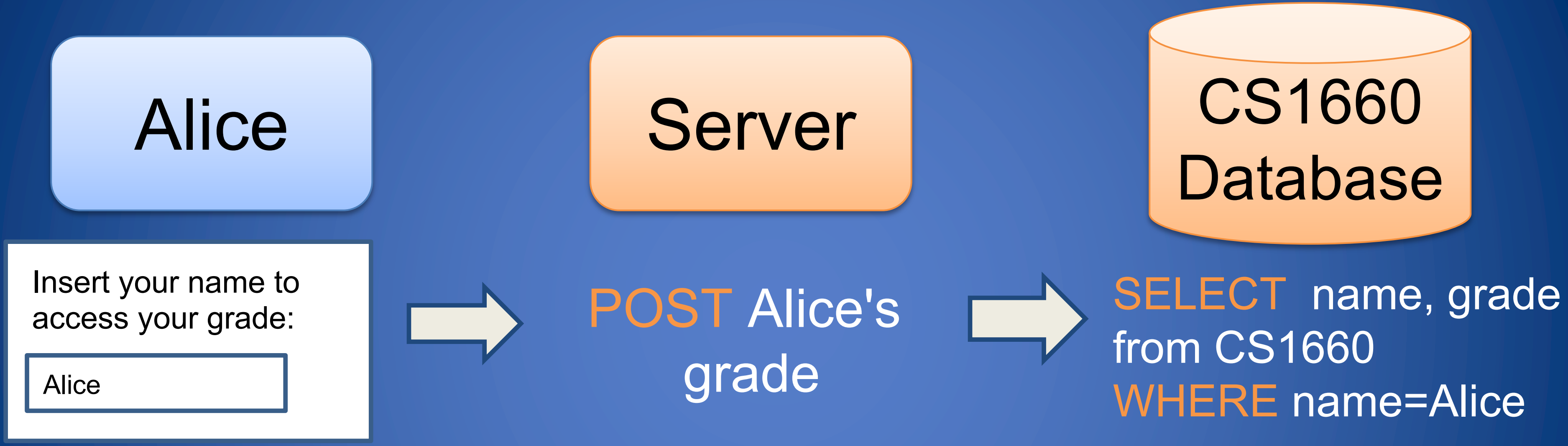
SELECT name, grade
from CS1660
WHERE name=Alice

Alice	A

200 OK: Alice, A

Student:	Alice
Grade:	A

SELECT: Data flow



Alice

Server

CS1660 Database

Insert your name to access your grade:

Alice

POST Alice's grade

```
SELECT  name, grade
from CS1660
WHERE name=Alice
```

Example Query: Authentication

```
SELECT * FROM CS1660 WHERE
Name=$username AND Password = hash( $passwd ) ;
```

Name	ID	Grade	Password	admin
Bernardo	345	-	H(password)	1
Bob	122	C	H(bob123)	0
Alice	543	A	H(a3dsr87)	0
…	…	…	…	…

Example Query: Authentication

```
SELECT * FROM CS1660 WHERE
Name=$username AND Password = hash( $passwd ) ;
```

- Student sets $username and $passwd

- Access granted if query returns nonempty table

UPDATE Function

```
UPDATE table SET attribute
    WHERE condition; -- comments
```

- Update records in table (UPDATE clause) that satisfy a certain condition (WHERE clause)

DELETE Function

```
DELETE FROM table
   WHERE condition; -- comments
```

- Delete records in table (DELETE clause) that satisfy a certain condition (WHERE clause)

ALTER Function

```
ALTER TABLE table
    ADD  element varchar(20); -- comments
```

- Alter the fields in table (ALTER clause) by adding a newe column with a certain size (e.g. varchar(20)

SQL Injection

Problem: How to handle user input?

```
SELECT attributes FROM users
    WHERE user = 'Alice' AND password = '<hash>'
```

Basic approach:

```
db->query("SELECT * from users where username=" . $user .
          " AND password = " . $hash "'");
```

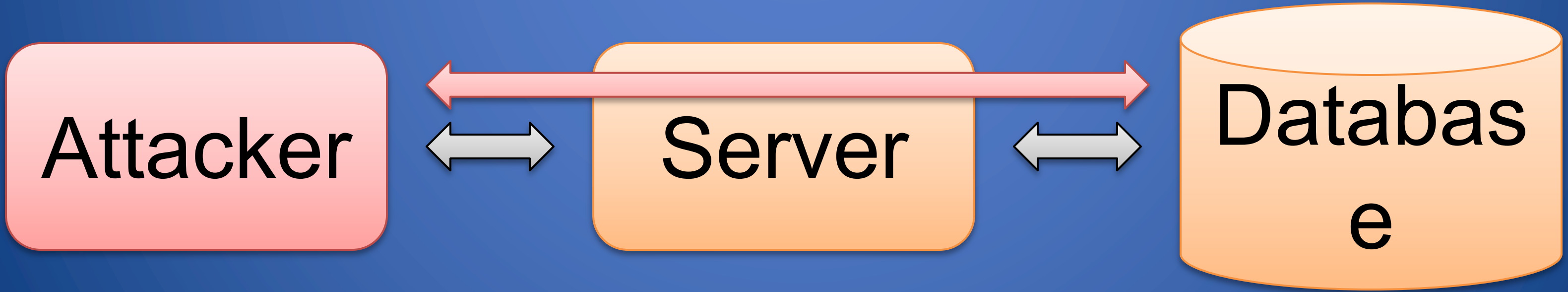
The problem

- User data could affect query string!

- What can we do??
- How to handle it??

SQL Injection

- Attacker bypasses protections on database
  - Causes execution of unauthorized queries by injecting SQL code into the database



SQL Injection to Bypass Authentication

```
SELECT * FROM CS1660 WHERE
Name=$username AND Password = hash( $passwd ) ;
```

$username = A' OR 1 = 1 --' $passwd = anything

Resulting query:

```
    SELECT * FROM CS1660 WHERE Name= 'A' OR 1 = 1 --' AND  …
```

SQL Injection for Data Corruption

```
SELECT * FROM CS1660 WHERE
Name=$username AND Password = hash( $passwd ) ;
```

- $username = A'; UPDATE CS1660 SET grade='A' WHERE name=Bob' --'
- $passwd = anything
- Resulting query execution

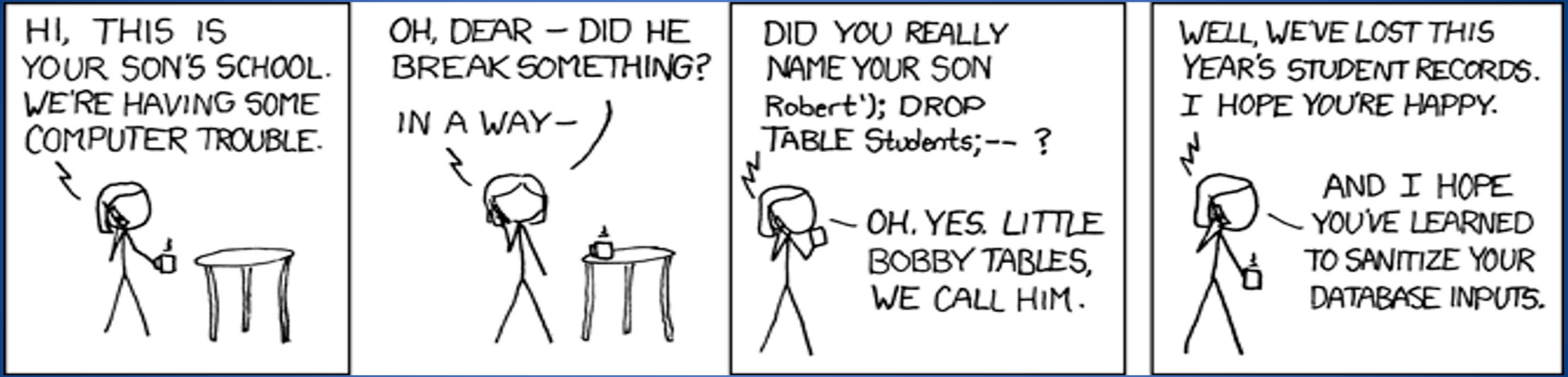
```
SELECT * FROM CS1660  WHERE  Name = 'A';
    UPDATE CS1660 SET grade='A' WHERE Name=‘Bob' --  AND ...
```

SQL Injection for Privilege Escalation

```
SELECT * FROM CS1660 WHERE
Name=$username AND Password =
    hash( $passwd ) ;
```

- $username = A'; UPDATE CS1660 SET admin=1 WHERE name=‘Bob' --'
- $passwd = anything
- Resulting query execution

```
SELECT * FROM CS1660  WHERE  Name = 'A';
    UPDATE CS1660 SET admin=1 WHERE name=‘Bob' --  AND …
```


HI, THIS IS YOUR SON'S SCHOOL. WE'RE HAVING SOME COMPUTER TROUBLE.
OH, DEAR – DID HE BREAK SOMETHING?
IN A WAY–
DID YOU REALLY NAME YOUR SON Robert'); DROP TABLE Students;-- ?
OH. YES. LITTLE BOBBY TABLES, WE CALL HIM.
WELL, WE'VE LOST THIS YEAR'S STUDENT RECORDS. I HOPE YOU'RE HAPPY.
AND I HOPE YOU'VE LEARNED TO SANITIZE YOUR DATABASE INPUTS.

Source: http://xkcd.com/327/

What We Have Learned

- Cross-Site Request Forgery (CSRF) attack
- CSRF mitigation techniques
- Web applications with a server-side database
  - Architecture and data flow
  - Simple SQL queries
- SQL injection
  - Example attacks and mitigation techniques